Advancing the art of the possible in remote sensing phenomena

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Amanda Ziemann's Early Career LDRD project

Scientific breakthroughs have been our legacy since 1943. When a researcher makes a discovery or develops a concept that alters the scientific community's belief of what is possible, it's a remarkable moment as science is forever changed.

The recent work of Amanda Ziemann (Space Data Science & Systems, ISR-3) does just that.

Ziemann's project, Geospatial Change Surveillance with Heterogeneous Data, accomplished what was once thought to be impossible. The stunning result: an approach for identifying changes in satellite remote sensing image pairs collected from two different sensing phenomena — in this case synthetic aperture radar (SAR) and multispectral imaging (MSI) sensors.

Laboratory Directed Research and Development, Early Career Research, funded the project.

Significance of new approach

Ziemann and her research team (James Theiler and Christopher Ren) have modified an existing LANL-developed technique (James Theiler's anomalous change detection) for application into this new arena. This may sound commonplace, but the importance of this new approach cannot be overemphasized: until now, no one has developed a method for change detection over a given scene using multiple sensing phenomena from different platforms.

"When the signals come from disparate phenomena, the math and physics underlying traditional change detection approaches no longer makes sense," Ziemann said. "What the signals are measuring is fundamentally different."

In fact, prior to presenting at the recent SPIE Defense + Commercial Sensing conference, Ziemann discussed the goal of her research with her former PhD thesis advisor from the Rochester Institute of Technology. His reaction: "What? That doesn't even sound possible."

SAR is a form of active-source radar that operates in the microwave spectrum to capture images of the Earth's surface structure at fine spatial resolution. These SAR

images are sensitive to surface changes or deformation and are commonly used for applications such as volcano monitoring and geothermal energy.

MSI sensors collect imagery in a multitude of spectral wavelengths, not just the red, green, and blue of traditional color photography; these sensors capture color information beyond what the human eye can see, and can be extremely sensitive to material changes.

Meeting national needs

As space-based remote sensing continues to become accessible in both government and commercial sectors, more satellite imagery enables increased comprehensive analysis and, potentially, more actionable intelligence. In practice, this analysis is challenged by the overwhelming volume of data, the diversity in sensor designs and modalities, and the stove-piped nature of image repositories for different satellite providers (e.g., NASA, Maxar Technologies).

Furthermore, as image analysts become overwhelmed by this ever-increasing deluge of imagery, the development of automated cueing and detection algorithms that "know where to look" is paramount.

Reports from the National Nuclear Security Administration (NNSA) and the National Geospatial-Intelligence Agency (NGA) have identified advances in change detection, tipping/cueing, and exploitation of commercial satellite imagery as research and development priorities.

The purpose of the research in Ziemann's project is to strategically address these national needs with algorithmic approaches that push the frontiers of remote sensing change detection in flexibility, sophistication, and scale. (See Figure 1.)

Crucial capability for 'persistent geospatial intelligence'

Ziemann's research enables multi-sensor satellite data integration for the discovery of important geospatial changes over time.

The major obstacle to using heterogeneous, or dissimilar, satellite data to monitor geospatial changes is this: subtle but real changes on the ground can be overwhelmed by artifacts that are simply due to the change in sensing modality. To address this, Ziemann and her team have advanced and implemented a mathematical framework that can effectively "normalize" for these changes in modality.

The project goals were: 1) advance state-of-the-art Laboratory methods to a salient change surveillance solution that is capable of leveraging multi-sensor, high-cadence satellite imagery, and 2) implement these methods on broad spatial and temporal scales as a first step towards true and persistent geospatial change surveillance. (See Figure 2.)

This project developed a crucial capability for "persistent geospatial intelligence" that can be extended to additional remote sensing assets.

Sponsors are already pursuing operationalizing this approach.

Figure 1 caption: *Overall concept for multi-sensor and multi-modal change surveillance.*

Figure 2 caption: *SAR to MSI anomalous change detection results over the construction site for the new LA Rams stadium in Inglewood, CA. In the detection map, dark gray corresponds to anomalous changes, middle gray corresponds to common changes, and white corresponds to stationary anomalies (present in each image).*